

THE ECONOMICS OF MANAGING BELDING'S GROUND SQUIRRELS IN ALFALFA IN NORTHEASTERN CALIFORNIA

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Abstract: We used estimates of yield loss from 1995 to 1999 and the reported costs and effectiveness of available control methods to provide a basis for developing a cost-effective management strategy for Belding's ground squirrels in alfalfa in northern California. Mean annual losses varied between US\$110/ha and US\$300/ha of alfalfa. Growers usually spend less than US\$25/ha on control methods that are implemented haphazardly and provide poor control. We suggest that growers can afford to spend more on control methods such as burrow fumigation or exclusion fencing that previously have been viewed as being too expensive. Control efforts should be focused on new fields supporting low-density populations.

Key words: alfalfa, anticoagulant baits, Belding's ground squirrel, burrow exploding devices, burrow fumigation, damage, economic loss, exclusion fencing, *Spermophilus beldingi*

Belding's ground squirrels (*Spermophilus beldingi*) are a major pest in high elevation alfalfa growing areas of northeastern California and eastern Oregon (White 1972, Sullins and Verts 1978). Alfalfa fields are ideal habitat for these squirrels providing them with favorable soil conditions for burrowing, and a nutritious food source. Population densities as high as 322 squirrels/ha of alfalfa have been reported (Sauer 1976).

Economic losses result from the feeding and burrowing activities of squirrels (Sauer 1976, Kalinowski and deCalesta 1981, Orloff et al. 1995, Whisson et al. 1999). Alfalfa is the squirrels' primary food source when living within the crop and first cutting yields may be reduced by 17.1 to 65.9% (Sauer 1976, Kalinowski and deCalesta 1981, Sauer 1984, Whisson et al. 1999). Whisson et al. (1999) reported losses of 48 and 18% in the first and second cuttings respectively from an alfalfa field that was heavily infested with squirrels. Yield losses are probably lower in subsequent cuttings because alfalfa growth rates are higher with the onset of warmer weather and plants are able to compensate for damage by squirrels (Whisson et al. 1999). In addition to the direct loss from feeding, losses result from the burrowing activities of squirrels. In 1998, growers reported approximately US\$1,000 damage (e.g., broken axles, flat tires, and dulled cutting bars) annually to harvesting equipment as a result of soil mounds made by squirrels and the badgers that prey on squirrels (D. Whisson et al. unpublished data). Other losses include a decrease in hay quality due to large amounts of soil and the presence of squirrel carcasses in hay bales, slower cutting times where burrows and mounds are numerous, and squirrel activities thinning alfalfa stands and contributing to weed infestations.

From 1970 to 1990 the primary method of control of Belding's ground squirrels was the aerial application of the acute rodenticide Compound 1080 (sodium

monofluoroacetate) on cabbage baits (Kalinowski and deCalesta 1981, Wright 1982). In 1990, Compound 1080 was deregistered for rodent control in California. Control methods now available include burrow fumigation using acrolein (Magnacide "H"™), aluminum phosphide (Phostoxin™ and Fumitoxin™), or gas cartridges; the application of anticoagulant baits; and shooting (Orloff et al. 1995). Use of a burrow-exploding device has also gained popularity in recent years. There is considerable uncertainty regarding the cost effectiveness of these approaches.

Our objectives were to estimate economic loss due to Belding's ground squirrels and to determine the relative costs and effectiveness of available control methods, in order to assist to develop a cost-effective management strategy for this pest.

METHODS

Yield loss

We used estimates of yield loss from a study of squirrel populations and damage in Butte Valley (Siskiyou County) from 1995 to 1999 and in Surprise Valley (Modoc County) in 1998 and 1999 (Whisson et al. 1999, D. Whisson et al. unpublished data). In that study, yield loss was approximated as the difference in dry matter yield between areas where squirrels were allowed to feed and areas from which they were excluded. The number of sites assessed and enclosure design varied among years. Damage estimates were based on 6 enclosures in a heavily infested 50.2-ha field in 1995; 10 enclosures at each of 3, 1-ha sites in 1996; 2 enclosures at each of 8, 1-ha sites in 1997; and 2 enclosures at each of 8, 1-ha sites per region in 1998 and 1999. In 1995 and from 1997 to 1999, enclosures were 3-m x 3-m, constructed from 0.9-m wide, 2.5-cm gauge chicken netting buried to a depth of 25 cm. In 1996, enclosures were circular (1-m diameter), constructed from 90-cm

wide, 2.5-cm-gauge chicken netting, and secured to the ground with metal stakes. This design was not as effective in excluding squirrels as that used in 1995. In 1995, the site was heavily infested with squirrels and chosen to provide an indication of maximum yield loss. From 1996 to 1999, sites were chosen to represent a range of potential squirrel population densities and damage levels, and thus provided a better indication of damage throughout a region.

Exclosures were constructed in March when alfalfa was breaking dormancy. In June each year, immediately prior to first cutting, alfalfa was hand-harvested inside the exclosures. Some exclosures were lost as a result of squirrels burrowing beneath the netting and feeding on the alfalfa inside the exclosure. At each site, alfalfa also was hand-harvested in 2, 3-m x 3-m areas (1995, 1997 to 1999), and in 10, 1-m diameter areas in 1996, where squirrels were not excluded.

Economic considerations

We estimated annual monetary value of yield loss based on current (1999) hay prices (US\$100/t for high quality dairy hay from the first cutting) and yield loss estimates for the first cutting only. We did not include indirect losses such as damage to harvesting equipment or reduced quality of hay. Costs and effectiveness of available control methods were derived from the literature. We compared the cost-effectiveness of methods by assuming a 90% reduction of the population as the

desirable level of control and repeating treatments until that level was achieved. We assumed that effectiveness of the control did not vary between treatments.

As a basis for calculating the cost of control methods involving burrow treatments we estimated the number of active burrows/ha at several sites of different stand age. In a 0.25-ha area of each site, we filled in all burrows with soil and counted those reopened after 48 hours. We then estimated the costs of the various burrow treatment methods for a potential range of active burrow densities.

RESULTS

Yield loss

Alfalfa yield as a result of squirrel feeding was reduced by up to 75% (mean = 37%) at individual sites (Table 1). Mean annual yield losses were between 1.1 and 3 t/ha/year representing an economic loss of between \$110/ha and \$300/ha.

Active burrows

The number of active burrows/ha was extremely variable between sites and throughout the year (Table 2). Squirrel burrows were not present in 1-year-old stands but generally increased in number with stand age. Similar densities of active burrows were observed in 2- and 3-year-old stands. In one 4-year-old field we recorded 1,092 active burrows/ha.

Table 1. Alfalfa yield loss from Belding's ground squirrels at first cutting (June/July) from 1995 to 1999 at sites in Butte Valley and Surprise Valley, northern California. Estimates represent losses from crops of different age and squirrel population densities (from Whisson et al. 1999; D. Whisson, S. Orloff and D. Lancaster, unpublished data).

Year	Location	Number of sites	Dry weight alfalfa loss (t/ha)		Economic loss (US\$/ha)
			Mean	SE	
1995	Butte V.	1	3.0	0.26	300
1996	Butte V.	3	2.1	0.21	210
1997	Butte V.	8	1.2	0.25	120
1998	Butte V.	8	1.5	0.23	150
1998	Surprise V.	8	1.7	0.21	170
1999	Butte V.	8	1.1	0.14	110
1999	Surprise V.	8	1.2	0.20	120
All years and areas		44	2.0	0.15	200

Table 2. Number of active burrows (AB)/ha from March to May for the period 1997 to 1999, in 1 to 4-year-old alfalfa stands in Butte Valley and Surprise Valley, northern California.

Month	Stand age (years)											
	1			2			3			4		
	Mean AB	SE	n	Mean AB	SE	n	Mean AB	SE	n	Mean AB	SE	n
March	0	0	4	28	19	4	136	44	7	624	110	4
April	0	0	4	159	132	4	132	63	7	279	80	10
May	0	0	4	177	104	4	108	44	7	258	90	10

Table 3. Available methods, costs of equipment and materials, and reported effectiveness (% reduction in population) for control of Belding's ground squirrels in alfalfa in California.

Control procedure	Reported effectiveness	Equipment and material costs (US\$)
Shooting	Unknown	\$0 (Ammunition provided by sports shooters)
Rodenticides: Bait stations ¹	52%	Bait: \$3.25/kg Stations: \$7.50 each
Spot baiting (bait is scattered by hand near active burrows) ²	68%	Bait: \$3.50/kg
Burrow fumigants		
Aluminum phosphide ³	30 to 40%	\$0.07/tablet
Gas cartridges ³	30 to 40%	\$0.90 per cartridge
Acrolein ⁴ (Magnacide "H")	90%	Equipment: \$1,200 fumigant: \$0.20/burrow
Burrow-exploding devices ⁵ (e.g. Rodentorch)	38%	Equipment: \$800 gases: \$0.05/burrow
Exclusion fence ⁵	Potentially >90%	Materials: \$20 per 3-m (roofing iron and 2 posts)

¹Matschke et al. (1999a) ²Matschke et al. (1999b) ³Orloff et al. (1995) ⁴Clark (1994)⁵D. Whisson, S. Orloff and D. Lancaster, unpublished data**Table 4. Cost per treatment per year and per 4-year stand life of available control methods to reduce a Belding's ground squirrel population by $\geq 90\%$ per year in a 1-ha stand of alfalfa (based on equipment and material costs listed in Table 3).**

Method	Initial number of active burrows	Cost (Materials ¹ + Labor ²)US\$/ha					Total per year	4-year stand life
		Treatment Number						
		1	2	3	4	5		
Acrolein	50	13	0	0	0	0	13	52
	300	78	0	0	0	0	78	312
	1,100	286	0	0	0	0	286	1,144
Aluminum phosphide	50	7	4	2	1	1	15	60
	300	39	23	14	8	5	90	360
	1,100	143	86	51	31	19	330	1,319
Gas cartridge	50	48	29	17	10	6	111	443
	300	288	173	104	62	37	664	2,656
	1,100	1,056	633	380	228	137	2,435	9,739
Burrow- exploding devices	50	6	3	2	1	1	13	56
	300	33	20	12	7	4	76	316
	1,100	121	73	44	26	16	279	1,116
Spot baiting ³	-	120	42	17	0	0	179	716
Bait stations ⁴	-	112	56	30	17	0	215	860
Exclusion fence ⁵	-	432	-	-	-	-	432	432

¹ Does not include initial purchase of equipment.² Labor costs are conservatively based on a wage of US\$7/hour:

Burrow treatments: 120 burrows treated/hour

Bait treatments: 15 min/ha/treatment

Fence: 6 days to fence a field with a 3,200-m perimeter

³ Assumes baiting at the rate of 11kg/ha (label-recommended rate) by 3 bait applications for the first treatment and reduced amounts needed in subsequent applications as the population is reduced. Spot baiting involves scattering bait by hand near active burrows.⁴ Assumes 9 bait stations are placed at 30-m intervals in a grid pattern/ha and the total amount of bait used per treatment per hectare is 33 kg/ha. This is based on label recommendations. Estimate does not include cost of bait stations (US\$68/ha).⁵ Based on constructing a fence made of roofing iron around a standard 50.2-ha circular field having a perimeter of 3,200 m. This is the most frequently occurring field size in the region.

Control methods, effectiveness and cost

There is considerable variation in the costs and effectiveness of available control methods (Table 3). Shooting has little or no cost to growers who allow sports shooters on their ranches; however, the effectiveness of this control method is unknown. The effectiveness of fences is also largely unknown; however, if constructed from durable materials and regularly checked for breaches by squirrels, fences may provide better than 90% reduction in activity of squirrels. Fumigating burrows with acrolein is the only method proven to achieve a 90% reduction in activity in one treatment. Other burrow treatments are at best 40% effective. Spot baiting is more effective than bait stations but is still only 68% effective.

As a result of low effectiveness in a single treatment, with some control methods up to 5 treatments were necessary to achieve a 90% reduction in squirrel activity (Table 4). Fumigating burrows with acrolein or aluminum phosphide, or using a burrow-exploding device were the most cost-effective techniques when there were ≤ 300 burrows/ha. Total annual costs for these methods were approximately US\$15 to treat 50 burrows/ha and between US\$76 and US\$90 to treat 300 burrows/ha. Although anticoagulant baits have a higher effectiveness per treatment compared to some of the burrow treatments, the higher cost of materials reduces the overall cost-effectiveness of this control method.

DISCUSSION

There are few alternatives to growing alfalfa in the intermountain region of northern California because of the short growing season (Orloff 1995), and Belding's ground squirrels clearly threaten the viability of growing this crop. Squirrels quickly invade new alfalfa fields so that by the second year of the stand's life, active burrows are numerous and economic loss occurs. Whisson et al. (1999) reported that yield loss in a newly planted field was similar to that in older fields where the squirrel population density was consistently high during the season. Mean yield loss in the first cutting from 1995 to 1999 varied from 1.1t/ha to 3.0 t/ha representing an economic loss of \$110/ha to \$300/ha annually. Damage to harvesting equipment and a decrease in quality of the stand represent additional losses.

Control programs for Belding's ground squirrels tend to be implemented haphazardly as a result of growers underestimating losses, the high cost of control, and the perceived low effectiveness of available control methods. Most growers are not prepared to spend more than about US\$25/ha on control procedures, and rely primarily on shooting (D. Whisson et al. unpublished data). Considering that annual yield loss from the first cutting may be as high as US\$300/ha, growers could

spend considerably more on effective control methods for a positive return. Choice of control methods (and therefore cost of the program) should be influenced by (i) the potential for squirrels to invade and damage an alfalfa field, (ii) the potential market value of the crop, (iii) the cost of the control procedure, and (iv) its effectiveness. All of these may vary considerably between areas and years.

Control programs should aim to prevent squirrel populations from becoming established in alfalfa fields. None of the available control methods are cost-effective for use in fields where populations are already large. However, in fields of low to moderate infestation (≤ 300 burrows/ha), burrow treatments with fumigants or burrow-exploding devices may prevent numbers from increasing for an annual cost of less than US\$100/ha. The optimal time to treat burrows is in late February or early March immediately following the emergence of squirrels from hibernation and prior to recruitment of juveniles. At that time, the alfalfa plants are still small enough to permit access to vehicles carrying application equipment. As with any burrow fumigant, only active burrows should be treated and sealing of burrow openings after treatment is recommended to maintain a high concentration of lethal gases inside the burrow system (Marsh 1994). This increases the time needed to treat a field, thereby reducing the cost-effectiveness of the control program. Repeat treatments also may be necessary to maintain the squirrel population at a low level.

Acrolein is the most cost-effective burrow fumigant available, costing approximately US\$0.26/burrow. Studies have shown single treatments using application rates of 20 ml acrolein/burrow to be effective in reducing activity of Belding's ground squirrels by 90% (O'Connell and Clark 1992, Clark 1994). However, some growers report poor results using acrolein when soils are cold, thus its use and effectiveness in some areas may be limited. Cold, dry soils also have been implicated as the cause for low effectiveness of aluminum phosphide and gas cartridges (Orloff et al. 1995).

Due to the perceived ineffectiveness and high cost of current control methods, new and novel rodent control devices and techniques receive significant attention by growers. This has been the case with burrow-exploding devices (Rodentorch™) that are marketed for control of burrowing rodents. The devices inject and ignite a mixture of oxygen and propane gases into a rodent's burrow system. The concussion caused by the explosion reportedly kills the rodents. Sullins and Sullivan (1992) tested the effectiveness of Rodentorch™ in reducing populations of ground squirrels in rangeland in Montana. Ignition of gases injected for 45 seconds into burrows reduced ground squirrel activity by 40.6%. The same device was tested in northern California for control of Belding's ground squirrels (D. Whisson et al. unpublished data). Activity there was reduced by

38.1% after one treatment of a 20-second injection per burrow. Despite its low effectiveness and therefore need for multiple treatments to provide control of a squirrel population (i.e., high labor costs), material costs are low, so the total cost of a program is similar to fumigating burrows with acrolein.

Anticoagulant rodenticides (diphacinone and chlorophacinone) have low effectiveness due to poor acceptance of grain or pelletized baits by Belding's ground squirrels in many areas (Sullins and Verts 1978) and relatively high cost. Consequently, rodenticides may only play a small role (e.g., perimeter baiting) in an integrated approach.

This analysis of the cost-effectiveness of available control methods assumes that a one-time 90% reduction in squirrel populations is needed each year to provide adequate control. However, unless control programs are coordinated on a regional scale, treated fields may be rapidly reinvaded and require additional treatment. Where this is likely or where conditions preclude the use of other control methods, an exclusion fence made of a durable material such as roofing iron might be the most cost-effective strategy. Although the initial cost might be high (US\$21,000 to fence a standard-size 50.2-ha circular field), additional annual control costs should be minimal.

The estimates of losses and costs of control we have presented here should be used by growers only as a guide for developing a management strategy specific to their ranches. No one method is likely to be effective in all situations and a management strategy will probably use a combination of techniques. Careful monitoring of squirrel populations, good timing in implementing control methods, repeating treatments where necessary, and keeping records of the effectiveness and costs of control methods implemented will be keys to the success of a control program. Mention of a product by name does not constitute our endorsement of that product.

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